

## LOW PROFILE SPINAL FIXATION SYSTEM

### Field of the Invention

5 The invention relates to spinal fixation systems and, more particularly, to spinal fixation systems that have a low profile.

### Background of the Invention

10 Spinal rods for immobilizing vertebral bones of the spinal column are typically anchored to the vertebrae via bone screws that extend through the pedicle into the vertebral bodies or by hooks that engage about the vertebrae. The rods are connected to the anchor members by generally yoke-shaped couplers that can be either integral with the anchor member head or separate components from the anchor member for use in polyaxial pedicle screw systems for spinal rod fixation. These prior systems employ some sort of compression member that is brought down into engagement either directly or indirectly with the spinal rod for securing it relative to the anchor member, and in polyaxial systems for securing the anchor member relative to the coupler.

15 For this purpose, the compression member and coupler typically are engaged via threading therebetween such that the compression member is threaded down into its locked position in or about the yoke-shaped coupler. Alternatively, wedge cam surfaces between radial flanges on the compression member and radial recesses in the coupler walls have also been employed to advance the compression member for pushing the spinal rod down into fixed position relative to the screw anchor member, see U.S. Patent No. 6,565,565, to Yuan, et al. The problem with the threaded or cam wedge systems of spinal rod locking is that to allow the compression member to advance relative to the coupler, the size or profile of the coupler as well as the compression member necessarily is increased. In other words, to have threads or cam surfaces formed on the coupler requires that the walls be provided with a sufficient axial extent for the advancement of the threaded or cammed compression member therealong. Additionally, many systems utilize a full spherical head on a bone screw located adjacent the rod, thereby requiring a greater coupler to capture the rod and the bone screw head.

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5 In polyaxial spinal fixation systems, the use of inserts between the head of the anchor member and the spinal rod has been proposed, see U.S. Patent No. 5,733,286 to Errico, et al. The large hemispherical insert of Errico, et al. is engaged on a concave recess formed in a screw head received in the coupler allowing the coupler to adjust relative to the polyaxial pedicle screw for receipt of the spinal rod in its desired position. However, the entire Errico, et al. system has a undesirably large profile as it employs a threaded set screw for clamping on the spinal rod, and the hemispherical insert extends well beyond the top of the screw head into the coupler channel through which the spinal rod is received.

#### 10 Summary of the Invention

15 In accordance with the present invention, a low-profile spinal fixation system is provided. In one aspect, a cam lock member of a coupling device is fixed against translation as it is turned so that a cam surface of the lock member causes an elongate member that extends generally along the spinal column, e.g. spinal rod, to be forced or pushed downward. As the cam lock member does not translate along the coupling device, the size of the coupling device can be kept to a minimum. Further, the low profile of the present system may allow for minimally invasive surgical procedures to be employed therewith such as with the components thereof being cannulated for use with a guide wire.

20 In another aspect, a polyaxial spinal fixation system is provided having a coupling member including an internal seat surface and a central bore sized to allow the anchor member to extend through the bore in several different orientations. The anchor member includes a head having an upper recess in which a low profile insert is provided. In a preferred form, the insert has an upper surface that is substantially flat. Other alternatives for the insert including the upper surface thereof are that the insert may or may not deform when compressed, the insert upper surface may have radially oriented concave paths or valleys so that the insert rotates to the closest path to meet with the

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spinal rod, or the insert may have a cup or peripheral ridge that deforms when compressed by the spinal rod to form a path without deforming the spinal rod. The upper surface is fit in the head recess with the insert sized so that the upper surface projects only slightly beyond the proximal end of the anchor member to keep the profile of the insert to a minimum. In one form, the insert upper surface is sized from the interface with the head recess at the bottom of the insert so that even with the anchor member pivoted to its maximum extent relative to the coupling member, the insert upper surface still projects slightly beyond the upper end of the anchor member head, e.g. by approximately 0.010 inch.

In a preferred form, the insert has an enlarged lower portion having a lower arcuate surface thereon for bearing against the concave recess surface of the anchor member head, and a central projection that extends upwardly from the lower portion and includes the flat upper surface thereon. The anchor member head preferably includes a retainer such as in the form of staked portions that allow the insert to self-adjust as the angle of the coupling member is adjusted with the flat surface projecting above the anchor member head for engaging the spinal rod.

In another preferred form, the cam member cooperates with a saddle or clamping member disposed between the cam member and the spinal rod. Upon turning of the cam member to lock the spinal rod, the cam member does not move axially along the coupling member but instead cams against the saddle member driving it axially toward the spinal rod until the spinal rod is secured between the clamping member and the insert. The cam member preferably is secured in assembly to the clamping member with a connector in the form of a dual-pronged spring clip so that the cam member stays assembled with the clamping member during a surgical procedure.

### **Brief Description of the Drawings**

FIG. 1 is a perspective view of a first form of the spinal fixation system in accordance with the present invention showing a bone screw and a coupling device

including a coupling member and a cam lock member for securing a spinal rod relative to the bone screw;

5 FIG. 2 is an enlarged perspective view of the spinal fixation system of FIG. 1 with the coupling member removed to better illustrate the cam lock member and to show the configuration of the head of the bone screw;

FIG. 3 is a cross-sectional view of the spinal fixation system showing a recess formed in the screw head in which a low profile anvil insert is received for clamping of the spinal rod thereagainst;

10 FIG. 4 is a cross-sectional view similar to FIG. 3 showing the relative sizes of the various components of the spinal fixation system;

FIG. 5 is a elevational view similar to FIG. 2 with the coupling member removed to show the radial flanges on the cam lock member and a bottom cam surface thereof;

15 FIG. 6 is a cross-sectional view of the spinal fixation system showing the recesses formed in the coupling member configured to receive the radial flanges on the cam lock member;

FIGS. 7-10 are various views of the cam lock member;

FIGS. 11-13 are various views of the yoke-shaped coupling member;

FIGS. 14 and 15 are elevational and sectional views, respectively, of the bone screw anchor member;

20 FIGS. 16-18 are various views of alternative camming system employing both a cam lock member and a saddle member;

25 FIG. 19 is an exploded perspective view of another form of the spinal fixation system in accordance with the present invention showing a bone screw and a coupling device including a coupling member, a cam lock member, a spring clip connector member, a clamping member, and an insert for securing a spinal rod relative to the bone screw;

FIG. 20 is a side elevation view partially in section of the system of FIG. 19 in a locked position showing a spinal rod secured between the clamping and insert members;

FIG. 21 is a side elevation view of the bone screw of FIG. 19;

FIG. 22 is an enlarged cross-sectional view of a head of the bone screw of FIG. 21;

FIG. 23 is a plan view of the bone screw head showing a recess for the insert;

FIG. 24 is a side elevation view of the insert of FIG. 19 showing an enlarged arcuate lower portion and a narrower upper portion projecting upward from the lower portion;

FIG. 25 is a perspective view of the insert showing a flat upper anvil surface thereof;

FIG. 26 is a plan view of the insert retained in the screw head recess;

FIG. 27 is an enlarged cross-sectional view of the screw head and the insert showing one of the staked head portions that retain the insert in the head recess;

FIG. 28 is a perspective view of the coupling member of FIG. 19 including a pair of integral spaced sidewall portions;

FIG. 29 is a plan view of the coupling member showing a bottom throughbore through which the bone screw extends, and a saddle located therewithin;

FIG. 30 is a side view of the coupling member showing the spacing between the sidewalls;

FIG. 31 is a side view of the coupling member rotated ninety degrees from the FIG. 30 view showing an enlarged width lower portion of one of the sidewalls at the base of the coupling member;

FIG. 32 is a cross-sectional view of the coupling member showing blind apertures toward the lower ends of the sidewalls;

FIG. 33 is a perspective view of the cam lock member of FIG. 19;

FIG. 34 is a bottom perspective view of the cam lock member showing a programmed cam surface at the bottom thereof;

FIG. 35 is a plan view of the cam lock member showing a drive socket including asymmetric drive surfaces;

5 FIG. 36 is a perspective view of the spring clip connector of FIG. 19 showing a pair of resilient prongs;

FIG. 37 is a side elevation view of the connector showing the spacing of the prongs and the flanged free ends thereof;

FIG. 38 is a side view of the clamping member of FIG. 19;

10 FIG. 39 is a side view of the clamping member rotated ninety degrees from the FIG. 38 view showing a pair of guide channels on one sidewall portion thereof;

FIG. 40 is a plan view of the clamping member showing a throughopening in the saddle member for the spring clip connector member;

15 FIG. 41 is a side elevation view of the cam lock member, and the clamping member in a unlocked position relative to the spinal rod;

FIG. 42 is a cross-sectional view similar to FIG. 41 showing the spring clip connector with the flanged ends of the clip prongs spaced from the cap member;

FIG. 43 is a side elevation view of the cam lock member and the clamping member in a locked position relative to the spinal rod; and

20 FIG. 44 is a cross-sectional view similar to FIG. 43 showing the clamping member shifted down along with the spring clip connector with the cap member axially fixed and rotated to its locked position.

### **Detailed Description of the Preferred Embodiments**

25 In FIGS. 1 and 2, a low profile spinal fixation system 10 in accordance with one form of the present invention is depicted. As shown, the spinal fixation system 10 includes a bone anchor member in the form of a bone screw 12 and a coupling device generally designated 14. The coupling device 14 is operable to secure an elongate

member in the form of spinal rod 16 in place relative to the bone screw 12. The coupling device 14 includes a compression or cam lock member 18 and a coupling member 20, which cooperate to secure the spinal rod 16 relative to the bone screw 12 anchored in a vertebral bone with the rod 16 generally extending axially along the spinal column. The coupling device 14 and specifically the cam lock member 18 and coupling member 20 are provided with a compact configuration. In particular, the cam lock member 18 and coupling member 20 are provided with a very low profile in a direction indicated by axis line 21 extending transverse and specifically orthogonally to the axis 16a of the spinal rod 16 fixed relative to the bone screw 12 by the coupling device 14, as best seen in FIG. 4.

More specifically, the low profile of the coupling device 14 is obtained by having the cam lock member 18 be effective to lock the spinal rod 16 without the need to advance the cam lock member 18 along the coupling member 20. In this regard, the coupling member 20 can be provided with a body 22 having side openings 24 and 26 through which the spinal rod 16 passes with the body 22 free of any threading or cam surfaces that cooperate with the cam lock member 18 for locking of the spinal rod 16 relative to the bone screw 12. Instead, the cam lock member 18 is fixed against translation relative to the coupling member 20, and preferably cooperates with the outer curved surface 28 of the rod 16 itself to secure it in position relative to the screw 12 in the system 10.

For this purpose, the cam lock member 18 has a generally annularly configured body 30 having a very short axial extent along turning axis 21 thereof via annular side surface 31 extending between its top and bottom surfaces 32 and 34. The top surface 32 is provided with driving surface portions 36 which cooperate to form a predetermined configuration for the receipt of a similarly configured drive tool for turning the cam member 18 between unlocked and locked positions thereof. The bottom surface 34 is programmed or contoured to provide a camming action on the curved surface 28 of the rod 16 when the cam lock member 18 is turned, as best seen in FIGS. 8 and 10 and as will be described more fully hereinafter.

Although less preferred in terms of maintaining a low profile for the spinal fixation system 10 herein, an intermediate clamping member in the form of saddle member 200 can be provided between the lock member 18 and spinal rod 16, as shown in FIGS. 16-18. The saddle member 200 has an upper cam surface 202 configured for cooperation with lock member cam surface 34 when the lock member 18 is turned to its locked position so that the saddle member 200 shifts downwardly along axis 21 for clamping against the rod 16. The saddle member is provided with a curved bottom surface 204 which substantially matches the curvature of rod surface 28 so that the saddle member 200 engages and pushes against the rod 16 without camming thereagainst. The cam lock member 18 can include a center opening 206 which receives a central post 208 projecting upward from the saddle member 200 to keep the cam lock member 18 and saddle member 200 oriented properly with respect to each other.

Similar to the cam lock member 18, the coupling member 20 also has a relatively small axial extent between top and bottom surfaces 38 and 40 thereof. As best seen in FIG. 11, the body 22 of the coupling member generally has a U-shaped or yoke configuration including opposing upstanding walls 42 and 44 spaced from each other by the rod openings 24 and 26 which can have an elongate configuration and be open to the top 38 of the coupling member body 22. Since the cam lock member 18 need not be advanced down along the walls 42 and 44 in the direction 21, the size in this direction can be minimized. By way of example and not limitation, the length or distance that the walls 42 and 44 extend between the top 38 and bottom 40 of the coupling member body 22 can be approximately 13.47 millimeters. The cam lock member 18 has a profile along axis 21 between the top 32 and the lowest most point of the contoured bottom cam surface 34 of approximately 5.08mm.

As shown, the annular body 30 of cam lock member 18 is sized to fit in internal space 46 of the coupling member 20 between the arcuate walls 42 and 44 thereof. The walls 42 and 44 are free of threading or cam surfaces that cooperate with the cam lock member 18 for shifting it to a locked position. More particularly, the inner surface 48 of



the coupling member 20 including arcuate surface portions 42a and 44a on the respective coupling member walls 42 and 44 are sized to closely receive the outer surface 31 of the cam lock member annular body 30 therebetween. These surface portions 42a and 44a are each free of threading or cam surfaces and thus only serve as guide surfaces for the cam lock member body 30 as it is turned about axis 21. Since the walls 42 and 44 do not need to be threaded or provided with recessed cam surfaces or the like, the size of the coupling device 14 can be kept to a minimum in the widthwise direction along the axis 16a of the spinal rod 16 as well. By way of example and not limitation, the diametrical width of the coupling device along spinal rod axis 16a can be approximately 10.03 millimeters. As can be seen in FIG. 7, guides 45 may be provided. The guides 45 are provided to initially pilot the cam lock member 18 into engagement with the walls 42 and 44.

Referring next to FIGS. 3 and 4, the illustrated spinal fixation system 10 has a polyaxial bone screw 12 whose orientation can be changed such that its longitudinal axis 12a extends transverse to the axis 21 of the coupling device 14 or is substantially aligned therewith. To this end, the coupling device 18, and specifically the coupling member 20 thereof is provided with a bottom throughbore 50 that extends through bottom wall 52 of the coupling member 20. The bottom wall 52 includes an inner surface portion 54 that tapers or curves inwardly from the surface portions 42a and 44a toward the center axis 21. The diameter across the inner surface portion 54 at its lowermost end 56 is sized to be smaller than an enlarged head 58 of the bone anchor screw 12. In addition, the diameter at 56 is sufficiently large to allow the threaded shank 60 depending from the screw head 58 to be advanced therethrough. In this manner, the inner surface portion 54 serves as a seating surface for the screw head 58. As an alternative, the diameter 56 is threaded with a thread oversized relative to the shank 60, thereby allowing the screw shank 60 to be loosely threaded through. In this instance, the diameter 56 is sized as to hold the shank 60 from passing easily through so that the screw 12 and coupling member 20 may be handled by a surgeon as a single component during the operation. In addition, the oversized threads allow the screw to be polyaxial in its orientation. As a further

alternative, the screw 12 may be passed through the diameter 56, and a c-ring or radial spring may be attached to the screw 12 immediately adjacent to the coupling member 20, thereby holding the two together and allowing the surgeon to utilize them as a single component during the operation.

5           The throughbore 50 extends centrally through the inner surface portion 54 and includes an enlarged diameter lower portion 62 formed by tapered or curved surface portion 64 on the bottom wall 52 of the coupling member 20. The tapered surface portion 64 extends from the smallest diameter of the bore 50 at 56 tapering outwardly relative to the center axis 21 of the coupling member 20 to the bottom surface 40 thereof.

10       The enlarged bore portion 62 allows the screw 12 to swivel or pivot to a variety of different orientations thereof relative to the coupling device 14. For example, in the illustrated form, the enlarged bore portion 62 allows the screw shank to pivot by 20 degrees on either side of the coupling device axis 21. As the screw 12 is pivoted, the outer arcuate surface 66 of the screw head 58 rides or shifts on the tapered seat surface

15       54 in the coupling member 20. Once the orientation of the coupling device 14 relative to the bone screw 12 fastened into a vertebral bone is determined with the spinal rod 16 extending through the coupling member 20 and up along the spinal column, the cam lock member 18 is then turned to its locked position. In the locked position, the cam lock member 18 anchors the rod 16 to the spinal column so it is fixed relative to the bone

20       screw 12 fastened into a vertebral bone with the bone screw head 58 clamped against the seat 54 therefor in the coupling member 20 thereby fixing coupling device 14 against shifting relative to the bone screw 12. The outer screw head surface 66 can be configured with concentric friction enhancing ridges or helical threads 67 to enhance the locking action between the screw head 58 and the seat 54.

25           Continuing reference to FIGS. 3 and 4, it can be seen that in the preferred and illustrated polyaxial spinal fixation system 10, the spinal rod 16 is pushed downwardly for being clamped against a small anvil insert 68. It should be noted that the previously described low profile coupling device 14 could be employed in spinal fixation systems

that are not polyaxial and/or which do not employ an insert as described hereinafter. Similarly, the present insert 68 could be advantageously employed in systems that employ threads or cams in the coupling members thereof.

5 The insert 68 has an upper anvil surface 70 that engages against the underside of the spinal rod surface 28 to maintain enhanced contact therewith over the curved surfaces of bone screw heads used in prior systems. The insert 68 has an upper surface 70 that may be substantially flat, may have radially oriented concave paths or valleys so that the insert 68 rotates to the closest path to meet with the spinal rod surface 28, or may have a cup or peripheral ridge that deforms when compressed by the spinal rod 12 to form a path without deforming the spinal rod. Accordingly, the insert 68 provides at least a line of contact with the curved rod surface 28, whereas prior systems engaging spinal rods with their curved fastener heads have a point contact with the spinal rod when clamped thereagainst which can more easily damage the rod 16.

15 The present insert 68 is also provided with a very low profile to minimize the space it takes up in the coupling member 20. More particularly, the bone screw anchor 12 has an upper concave recess 72 formed in the screw head 58 thereof to form a cup-shaped wall 73 of the screw head 58 having an upwardly opening cavity 74 in which insert 68 is received. The insert 68 has an arcuate bottom surface 76 having a curvature similar to that of the concave surface 72 so that it can shift or slide thereon as the polyaxial screw 12 is moved to various orientations thereof relative to the coupling device 14. The insert 68 is sized such that the distance between the lowermost point of the bottom surface 76 and the top flat surface 70 is slightly larger than the depth of the cavity 74. In this manner, the flat surface 70 projects only slightly above the proximal end 78 of the screw 12 at the top surface 80 of the screw head wall 73 extending about the cavity 74, as can be best seen in FIG. 5. Accordingly, the insert 68 only nominally increases the height of the screw head 58 in the internal space 46 of the coupling member 20 allowing the coupling device 14 to maintain its low profile character, as previously described. By way of example, the distance between the bottom 40 of the coupling

member 20 and the spinal rod axis 16a with the rod 16 clamped against the insert 68 can be approximately 6.34 millimeters. It is preferred that the insert 68 has a greater elastic deformation than the coupling member 20 or the spinal rod 16 so that it has a greater spring-like property. Accordingly, the material of the insert 68 preferably has a lower Young's Modulus than the coupling member 20 and spinal rod, thereby reducing the criticality of the dimensional tolerances. Alternatively, a material, such as cobalt chrome, may be used for the insert 68 that is harder than the rod to increase the clamping force therebetween.

In the preferred and illustrated form, the small, low profile insert 68 has an enlarged lower portion 82 including the arcuate bottom surface 76 thereon with an upper portion 84 projecting centrally upward from the enlarged lower portion 82 and having the top surface 70 thereon. Accordingly, the top surface 70 is narrower in the directions orthogonal to the axis 21 than the bottom surface 76 so that a shoulder surface 86 is formed between the insert portions 82 and 84. The above-described structure for the low profile insert 68 provides it with an inverted mushroom-like configuration with the enlarged head portion 82 riding on the concave recess surface 72 in the screw head 58.

To keep the insert 68 in the cavity 74 formed in the screw head 58, a retainer such as in the form of staked portions 88 of the screw head wall 73 are provided. These staked portions 88 extend radially inward at the proximal end 78 of the screw 12 so as to be in interference with the shoulder surface 86 on the insert 68 for keeping it retained in the cavity 74, and in a substantially upright position while providing for a small amount of rotation therein as shown in FIGS. 3-6. It should be noted that the term rotation is meant to include any pivoting of the insert within the screw head 58. As can be seen, the insert 68 is not fixed with respect to the coupling member 20, instead being retained in the screw head with the staked portions 88. This allows the insert 68 to have a slight mobility, or play, and allows the insert 68 to shift independently of the screw 12 and the rod surface 28. Accordingly, the insert 68 may follow the rod surface 28 and seat itself between the rod surface 28 and the screw head 58 for a self-aligning capability.

As previously mentioned, the cam lock member 18 does not translate along the coupling member 20 when it is turned to its locked position. In order to keep the cam lock member 18 fixed against movement in the direction along axis 21, it is provided with radial flanges 90 and 92 extending radially outwardly from the annular body 30 at diametrically opposite positions thereon. The flanges 90 and 92 are received in correspondingly configured recesses 94 and 96 formed in the coupling member walls 42 and 44, as can be seen in FIG. 6. The recesses 94 and 96 have an arcuate configuration extending about axis 21 as do the radial flanges 90 and 92 for fitting therein and allowing turning of the cam lock member 18 between unlocked and locked positions thereof. The flanges 90 and 92 are received in the recesses 94 and 96 when the cam lock member 18 is turned toward its locked position. With the cam surface 34 camming on the rod surface 28, the flanges 90 and 92 in the closely conforming recesses 94 and 96 prevent the cam lock member 18 from shifting upwardly away from the spinal rod 16 and instead forces the spinal rod 16 down into clamping engagement with the insert 68 which, in turn, causes the screw head 58 and specifically outer head surface 66 to be clamped against the seat surface 54 in the coupling member 20 thus fixing the coupling device 14 relative to the bone screw 12 and anchoring the spinal rod 16 to the spinal column.

The downwardly directed clamping forces exerted by the cam lock member 18 between the screw head 58 and the bottom wall 52 of the coupling member 20 and in particular between the respective engaging surfaces 66 and 54 thereof can cause the coupling member walls 42 and 44 to spread apart. Accordingly, the flanges 90 and 92 are also provided with distal portions 98 and 100, respectively, that extend along axis 21. In this instance, the distal portions 98 and 100 are shown as being upturned from the distal ends of the radial flanges 90 and 92 although they could likewise be configured so that they extend downwardly in the direction along axis 21. The recesses 94 and 96 also include portions 102 and 104, respectively, that extend in an upward direction along the axis 21 in the coupler member walls 42 and 44 for receiving the upturned distal portions 98 and 100 on the respective radial flanges 90 and 92. With the flange portions 98 and

100 received in the recess portions 102 and 104, any spreading action of the walls 42 and 44 during the locking operation with turning of the cam lock member 18 is resisted.

As previously mentioned, the cam lock member has a contoured bottom cam surface 34 that cams on the curved cam surface 28 of the spinal rod 16. The cam surface 34 is best seen in FIGS. 8 and 10. In the illustrated and preferred form, the cam surface 34 is contoured to provide three distinct regions defined in relation to their action on the spinal rod 16. A first concave region 106 is provided to substantially mate with the rod surface 28 in the unlocked position. Concave surface region 106 extends across the bottom 34 of the cam lock member body 30 and can be aligned with the radial flanges 90 and 92. Accordingly, the radial flanges 90 and 92 will be disposed slightly above the bottom 34 of the cam lock member body 30 to accommodate the spinal rod curved surface 28 extending therebelow with the cam lock member 18 in the unlocked position thereof. In this position, the flanges 90 and 92 are not received or fully received in the recesses 94 and 96 therefor.

Diametrically opposite sections 106a and 106b of the concave surface region 106 are provided so that rotation of the cam lock member 18 in the unlocked position does not cause a camming action to occur with only a slight initial turning action thereof. With the spinal rod surface 106 aligned with the surface portions 106a and 106b, the spinal rod 16 is still loosely received under the cam lock member 18 and is not cammed thereby. Beneficially, the spinal rod 16 is captured under the cam lock member 18 so as to provide the surgeon with greater freedom of manipulation before finally locking the cam lock member 18. With continued turning of the cam lock member 18, the camming action begins at ramp regions 108 and 110 that are diametrically opposite to each other on the cap bottom surface 34 and project downwardly from the adjacent surface sections 106a, 106b along direction 21. The ramp regions 108 and 110 are configured so that the rod 16 is progressively pushed downward in the direction 21 as the cam lock member 18 is turned about the turning axis 21 toward the locked position. Accordingly, in the unlocked position these ramp surface regions 108 and 110 on the bottom cam surface 34

extend down along either side of the spinal rod 16 so as to advantageously take up the space on either side thereof thus serving to keep the space occupied by the cam lock member 18 in the coupling member 20 to a minimum for providing the overall coupling device 14 with a low profile.

5 Continued turning of the cam lock member 18 toward the locked position causes the rod surface 28 to be engaged against diametrically opposite generally flat surface regions 112 and 114 adjacent to the ramp surface regions 108 and 110, respectively. In an alternative form, the surface regions 112 and 114 may be a valley shape providing a depression such that the rod 12 is received into the depression. The surface regions 112  
10 and 114 are not inclined relative to the axis 21 like the preceding ramp surfaces 108 and 110 and are the lowest point of engagement of the cam surface 34 with the rod surface 28. With the cam lock member 18 turned so that the rod surface 28 is only engaged by the surface regions 112 and 114, the cam lock member 18 is in its fully locked position with the cam lock member flanges 90 and 92 fully received in the corresponding yoke wall recesses 94 and 96 therefor, as shown in FIGS. 1 and 6. Continued turning of the  
15 cam lock member in the same direction after the fully locked position has been reached is prevented by abutment surface regions 116 and 118 adjacent to the surface regions 112 and 114, respectively. These abutment surfaces 116 and 118 extend further downwardly in direction 21 from the surface regions 112 and 114.

20 Accordingly, the illustrated and preferred programmed cam surface 34 provides several stages for the camming and locking action on the spinal rod 16. As shown, the cam lock member 18 can be rotated by approximately 20 degrees from the unlocked position before the rod surface 28 reaches the ramp surfaces 108 and 110. At this point, the rod 16 is cammed downwardly and the cam lock member can be turned for another  
25 60 degrees before the rod surface 28 reaches the flat locking surfaces 112 and 114. The cam lock member 18 can then be turned by another 20 degrees before the rod surface 28 abuts against the stop surfaces 116 and 118 and the cam lock member 18 is in its fully locked position. Thus, there is approximately 100 degrees of rotation of the cam lock

member 18 that is required from the fully unlocked position to the fully locked position with 20 degrees of play provided before the camming action begins and the camming of the rod 16 occurring over the final 80 degrees of rotation to the fully locked position.

Turning to more of the details, as previously mentioned, the cap cam lock member 18 includes drive surface portion 36 recessed in the top surface 32. As best seen in FIG. 2, the drive surface portion 36 can be formed with a plurality of lobes extending radially outward from the center axis 21 for receiving a similarly lobed drive tool. The lobe drive surface portions 36 provide an increased area for surface contact and torque transmission between the drive tool and the cam lock member 18.

For the bone screw 12, the screw head 58 is provided with peripheral driving surfaces 120 and recessed notches 122 formed in the proximal end 78 of the screw head and recessed or notched into the top surface 80 thereof, as can be seen in FIG. 15. In this manner, a driving tool having peripheral prongs for fitting in the notches 122 can be utilized while the anvil insert 68 is in the screw head cavity 74 and slightly projecting out therefrom, as previously described.

Referring to FIGS. 1 and 11-13, it can be seen that the yoke coupler walls 42 and 44 are provided with a key slot 124 and 126, respectively, with the slots 124 and 126 having enlarged central throughbore 128 and 130 extending through the walls 42 and 44. The slots enable the coupling device 14 to be held as by arms on a device used to insert the spinal rod 16 into the coupling member 20, e.g. a rod persuader. The arms can have engaging ends that locate in the slots 124 and 126 and extend into the throughbores 128 and 130.

Referring now to FIGS. 19-44, a low profile spinal fixation system 500 for securing a spinal rod 16 in accordance with another form of the present invention is depicted. As can be seen in FIGS. 19 and 20, the system 500 includes a bone anchor member such as screw 502 and a coupling device 504 for securing the spinal rod 16 relative to the bone screw 502. The coupling device includes a coupling member in the form of a unitary yoke 512, an insert in the form of anvil 516, a cam lock member in the



5 form of cap 518, a connector member in the form of a spring clip 519, and a clamping member in the form of a saddle 520. The fixation system 500 is similar to the embodiment of FIGS. 1-18 in that the cap 518 and yoke 512 are provided with a very low profile in the direction indicated by yoke axis line 21 extending transverse and specifically orthogonally to the axis 16a of the spinal rod 16 fixed relative to the bone screw 502 by the coupling device 504, as best seen in FIG. 20.

10 The screw 502 is directed through the yoke 512 and attaches the yoke 512 to a bone or bone fragment. The screw 502 has a head 536 with a recess 554, and the recess 554 receives the anvil 516. The spinal rod 16 is received within an internal space or channel 601 in the yoke 512 and is seated on top of the anvil 516. The screw 502 is preferably a polyaxial screw, and the anvil 516 is permitted to move within the head 536 of the screw 502. Accordingly, prior to the system 500 being secured, the screw 502 may move relative to the yoke 512 so that the yoke 512 and screw 502 may be selectively positioned to assume different orientations relative to each other so that their respective axes 21 and 544 are not necessarily aligned with each other, and the anvil 516 may move and pivot or rotate relative to the screw 502 so that the anvil 516 may be properly positioned by orienting itself with the outer surface 28 of the rod 16 similar to the previously described anvil 68.

15 The rod 16 is secured or locked within the yoke 512 with the cap 518 and saddle 520. As will be discussed below, rotation of the cap 518 has the dual function of securing the cap 518 within recesses 642 in the yoke 512 and of forcing the saddle 520 against the rod 16 to lock the rod 16 between the saddle 520 and the anvil 516. The saddle 520 and cap 518 are secured together in assembly by a distinct connector in the form of the dual-pronged, spring clip 519.

20 In FIGS. 21-22, the bone screw 502 is depicted. The bone screw 502 includes a tip 530 at a distal end 532, a proximal end 534 including a screw head 536, a shank 538 including external threads 540 for driving and securing the screw into a bone or bone fragment, and a neck 542 where the head 536 and the shank 538 meet. The screw 502

is driven by rotation around its central longitudinal axis 544. The tip 530 of the screw may be provided with a variety of configurations such as a self-tapping structure or self-drilling structure, as is known. As discussed, the screw 502 is preferably polyaxial, and the head 536 is diametrically larger than the shank 538 at the neck 542. The polyaxial features of the screw 502 allow the screw 502 to be secured to a bone in a desired orientation for proper fixation to the bone while allowing the yoke 512 to be oriented relative to the screw 502 in an orientation desired for seating a rod 16 therein.

The head 536 of the screw has an arcuate or slightly ramped top surface 550 which meets a peripheral outer surface 552 of the screw head 536. The peripheral outer surface 552 of the screw head 536 has a generally arcuate or spherical profile 570. The profile 570 is interrupted with a series of concentric ridges or circular grooves 572 cut therein. As discussed above, the screw 502 is polyaxial so that its orientation relative to the yoke 512 can be precisely positioned. When the coupling device 504 is secured to the screw 502, the grooves 572 grip or cut into the interior of the yoke 512 to immobilize the screw 502 in the desired position against the yoke 512. By way of example, the grooves 572 can be approximately 0.012 inches in width to provide sufficient gripping strength or purchase in the yoke 512.

The top surface 550 includes an upwardly opening recess 554 formed therein for receiving the anvil 516. As can be seen in FIGS. 24-27, the recess 554 has an arcuate or, preferably, spherical bottommost surface portion 556 sized and configured to allow the small anvil 516 to shift when seated in the recess 554. To this end, the anvil 516 has a bottom surface 558 supported on and slidable against the bottommost surface portion 556. Furthermore, the recess 554 has two pair of diametrically opposed notches 560, each pair perpendicularly oriented from the other pair, for receiving similarly configured prongs of a driver without interfering with the anvil 516 therein. The top surface 550 includes a retainer or staked portion in the form of short tabs 562 located at the opening to the recess 554 and between each notch 560. Prior to disposing the anvil 516 in the recess 554, the tabs 562 rise upwardly from the top surface 550 in the axial direction so

that the tabs 562 do not hinder insertion of the anvil 516. Once the anvil 516 is located in the recess 554, the tabs 562 are deflected over to extend radially into interference with the anvil 516 while still allowing the anvil 516 to move within the recess 554 but be captured therein by the tabs 562. After assembly, heat or other treatment may be utilized to relieve residual stresses within the bent tabs 562.

The anvil 516 has a bottom portion 580 with a generally arcuate or spherical bottom surface 558 which rests against the bottommost portion 556 of the seat 554. Accordingly, the anvil 516 may pivot or rotate within the recess seat 554. The anvil 516 further includes a seat portion 582 extending centrally upward from the anvil bottom portion 580 to a top surface 584 with a transverse shoulder surface 585 between the anvil portions 580 and 582. As seen best in FIG. 27, with the anvil 516 seated upright in the recess 554 there is a gap spacing 587 between the bent tabs 562 and the anvil transverse surface 585. This gap spacing 587, along with the narrower width of the anvil upper portion 582 extending generally upwardly in the recess 554, allows for the anvil 516 to toggle or pivot in the recess 554 with the anvil surface 558 sliding on the recess surface 556 until the surface 585 abuts against one or more of the tabs 562.

The seat portion 582 is preferably frusto-conical so that compression stresses thereon are distributed through to the bottom portion 580 while minimizing the possibility of damage to the outer edge 584a of the top surface 584. Like the previously described anvil 68, the anvil bottom portion 580 is enlarged relative to the upper portion 582 so that the seat portion 582 may move within the recess 554 and in the space 587 between the anvil shoulder surface 585 and the tabs 562.

When the rod 16 is inserted within the yoke 512, the side surface 28 of the rod 16 is advanced into contact with the anvil 516. If the bone screw 502 is deflected, angled or secured so that its central axis 544 is not coincident or aligned with the yoke central axis, the anvil 516 is initially deflected or tilted in a similar direction. As the rod 16 is secured and forced against the anvil 516, the anvil 516 pivotable in the recess 554 will shift to require the minimize distance between the rod 16 and the bottom surface portion 556 of

the recess 554. As the anvil top surface 584 is flat while the bottom surface 558 is spherical, the shortest distance from the top surface 584 to the bottom surface 558 is through the geometric center 588 to the center 590a of the bottom surface 558.

As discussed herein, in order to have a low profile, it is preferred to minimize the height of the anvil 516 while remaining above the top surface 550 of the screw head 536. The anvil top surface 584 is sized so that, when angled or deflected due to the angle or deflection of the bone screw 502, at least a portion of the top surface 584 is contacted by rod 16 being advanced towards the anvil 516 in the yoke 512. Accordingly, the anvil 516 is self-righting as the rod 16 contacting the anvil top surface 584 forces the anvil 516 to shift to align tangentially its minimum height, as discussed above, with the surface 28 of the rod 16.

The polyaxial screw 502 is inserted through the yoke 512 and secured to a bone, and the rod 16 rests against the top surface 584 of the anvil 516. As the orientation of the screw 502 relative to the yoke 516 may pivot, the anvil 516 may pivot within the recess 554 so that the top surface 584 remains tangential to the generally cylindrical outer surface 28 of the rod 16. Generally, the anvil 516 and screw head 536, and specifically the recess 554 thereof are sized relative to each other so that the anvil top surface 584 always extends slightly beyond the top of the cup-shaped head wall 536a at the head upper surface 550 even with the screw 502 pivoted to its maximum extent relative to the yoke 512, e.g. twenty degrees from axis 21. More specifically, as previously mentioned, the anvil bottom portion 580 can have its bottom surface 558 curved to have a generally spherical configuration with a radius 589, as shown in FIG. 24. As the bottom surface 558 pivots in the arcuate recess surface 556, the radius 589 extends from the general center of rotation 588 of the anvil 516. The anvil 516 is fashioned from a generally spherical component to have the shoulder surface 585 and the seat portion 582. Accordingly, the height distance 586 from the center of rotation 588 to the anvil seat surface 584 is at least slightly less than the length of the radius 589. By way of example, the height distance 586 can be approximately 0.043 inches and the radius 589 can be

approximately 0.0625 inches so that the distance 586 is approximately 0.0195 inches less than the radius. If the height 586 of the anvil top surface 584 is increased significantly, the width of the anvil top surface 584 must be increased which would limit the polyaxial motion of the screw 502 as the anvil 516 would come into contact with the tabs 562 with a smaller degree of tilt or deflection. If the height 586 of the anvil top surface 584 is decreased significantly, the rod 16 would not be able to contact anvil top surface 584 without contacting the screw head 536 first, an event that becomes more acute at greater deflection angles.

Thus, the configuration of the anvil 516 and the recess 554 including the tabs 562 extending therein allows the anvil 516 to pivot to follow the position of the rod 16 and to promote self-righting of the anvil 516. In addition, the size of the anvil 516 between surfaces 584 and 558 including the height 586 is selected so that the top surface 584 is lower than a top surface of a completely spherical screw head would be to keep the profile of the anvil assembly including the screw head 536 and anvil 516 in the yoke 512 to a minimum. That is, if the screw head 536 were spherical, the height of the top of the screw head 536 would be higher than the top surface 584 of the anvil 516, which would increase the overall height of the system 500. When the coupling device 504 is in its locked condition, the top surface 584 of the anvil 516 may slightly deform, thereby forming a depression which is tightly engaged with and conforming to the outer surface 28 of the rod. By deforming, the anvil 516 and rod 16 form a substantially flush mating surface contact, as opposed to a line contact. The bottom surface 558 of the anvil 516 includes a small flat 590 which assists in minimizing friction between the anvil bottom surface 558 and the seat 554.

As has been stated, the screw 502 is inserted through the yoke 512. As can be seen in FIGS. 28-32, the yoke 512 has an enlarged base portion 600 and a shape with a generally cylindrical outer surface 602 formed by a pair of opposed side wall portions 604, 606 extending from the enlarged base 600 and defining a channel 601 for receiving a rod 16 therebetween. The channel 601 may have a liner made of, for instance, a

polymer such as PEEK, for promoting low-friction contact between the rod 16 and the channel 601. A recess 608 including the channel 601 is formed between the walls 604, 606 with vertical axis 21, and the recess 608 includes a throughbore 612 in the bottom or base 600 of the yoke 512 through which the screw 502 is inserted. The throughbore 612 may be constructed as the throughbore 50 of the coupling member 20, discussed above, and may include a polymer liner, such as PEEK, for promoting low-friction polyaxial movement of the screw 502 therein.

In similar fashion to that depicted in FIGS. 1 and 11-13, the outer surfaces 602 of the yoke walls 604, 606 are provided with a key slot 124 and 126, respectively, with the slots 124 and 126 having enlarged central throughbore 128 and 130 extending through the walls 604, 606. The slots enable the coupling device 514 to be held as by arms on a device used to insert the spinal rod 16 into the yoke 512, e.g. a rod persuader. The arms can have engaging ends that locate in the slots 124 and 126 and extend into the throughbores 128 and 130.

The outer surface 602 of the yoke 512 also includes blind apertures or holes 650. As can be seen best in FIG. 32, the blind hole 650 does not extend into the interior recess 608, instead terminating at a thin wall portion 652 of the yoke 512. Once the screw 502 and its secured anvil 516 have been inserted through the throughbore 612, the thin wall portion 652 adjacent each blind hole 650 is deformed into the recess 608 so that the screw 502 and anvil 516 subassembly cannot be pulled back out of the yoke 512 and thus stays in assembly therewith. With the screw 502 retained in the yoke 512, the surgeon need only handle the screw 502, yoke 512, and anvil 516 as a single item or assembly.

In the preferred illustrated form, the yoke 512 has a high strength unitary construction as described below. Each integral sidewall portion 604, 606 has a top surface 620, end surfaces 622, and inner surfaces 624. The inner surface 624 of each wall 604, 606 is generally a mirror of the surface on the opposed wall. The walls 604, 606 cooperate with each other to form two U-shaped interior surfaces 626, each with a pair of leg portions 628 that are vertically opposed in a region from the top surface 620

extending downward. Each pair of leg portions 628 meets a generally semi-circular portion 630 interconnecting the leg portions 628. To the outside of the surfaces 626, the cylindrical outer surface 602 of the yoke 512 is truncated to form the end surfaces 622 of the walls 604, 606, and is truncated to form end surfaces 632 on the base 600. The truncation of the ends of the yoke 512 reduces the overall size of the yoke 512 in a widthwise direction transverse to the axial direction 21. Referring to FIGS. 28 and 31, as the base 600 has a greater dimension between its end surfaces 632 than the walls 604, 606 have between their end surfaces 622, there is a shoulder 634 formed between the end surfaces 632 and the end surfaces 622. The enlargement of the base portion 600 at the lower end portions of the walls 604 and 606 provides increased strength to the yoke 512 in the area of highest stress concentration where the rod 16 is clamped down on the curved surface portions 630 of the yoke 512 toward the bottom end thereof. The cut-away of the yoke 512 along the side wall portions 604 and 606 extending up from the base portion 600 keeps the width of the yoke 512 for a majority of its axial length to a minimum, as previously described.

The inner surfaces 624 of the walls 604, 606 each include a surface 640 having a generally cylindrical configuration extending between the U-shaped interior surfaces 626. The cylindrical surfaces 640 and interior surfaces 626 define interior recesses 642 extending circumferentially in the sides with a constant cross-section. Guides 643 in the form of small projections or nubs are located on the interior surface 626, as depicted in FIG. 28, above the recesses 642. When the saddle 520 is inserted into the yoke 512, as seen in FIG. 29, the guides 643 assist in proper positioning of the saddle therein, as will be discussed below. In addition, the guides 643 serve as detents to provide distinct rotary positions for the cap 518 as it is turned. Similar to the cam lock member 18 described above, the cap 518 has a generally cylindrical body portion 644 with an outer surface 645 including a number of recesses arranged thereon in the form of generally vertical, arcuate indentations 647 circumferentially spaced about the outer surface 645. The indentations 647 cooperate with the detents 643 to provide a tactile indication to a surgeon as to how

far the cap 518 has been turned in the yoke 512 as the nub detents 643 snap into and out from the indentations 647. For instance, with the cap 518 in its locked position, the detents 643 and indentations 647 can be spaced so that a predetermined number of clicks are generated when the cap 518 is turned to its completely locked position, e.g. one-hundred degrees from the unlocked position.

The recesses 642 extend generally horizontally for receiving the cap 518 and, more specifically, a pair of radial flanges 656 of the cap 518 that fit into the correspondingly configured recesses 642 of the yoke 512 in a manner similar to previously described flanges 90 and 92 and corresponding recesses 94 and 96. The radial flanges 656 and recesses 642 keep the cap 518 from shifting axially along the yoke 512 as it is turned so that the camming action generated between the cap 518 and saddle 520 only causes axial shifting of the saddle 520 toward and against the spinal rod 16. Each of the flanges 656 includes a flat ramp lead-in surface 657 that assists in guiding the flanges 656 as they are turned from the slots formed between the sidewall portions 604 and 606 with the cap 518 in its unlocked position to shift the flanges 656 to be inserted in their respective recesses 642. No camming action, however, occurs between the surfaces of the recesses 642 and the flanges 656 that shifts the lower surface 700 of the saddle 520 relative to the cap 518. As explained below, the camming action is solely generated between the bottom surface 704 of the cap 518 and the top surface 702 of the saddle 520.

The radial flanges 656 also include upturned portions 658 at their distal ends 659, and the recesses 642 also include corresponding portions 649 that extend in an upward, axial direction in the respective yoke walls 604, 606 for receiving the upturned flange portions 658 therein. With the flange portions 658 received in the corresponding recess portions 649, any spreading action of the yoke walls 604, 606 during the locking operation with the turning of the cap 518 is resisted.

As depicted in FIGS. 41-44, the cap 518 and the saddle 520 each define central openings 670, 672, respectively, through which the clip 519 extends. The cap opening



670 is segmented between a lower portion 670a and an upper portion 670b that steps open to a diameter larger than that of the lower portion 670a. An annular shoulder seating surface 674 is at the transition between the lower portion 670a and the upper portion 670b of the cap opening 670. The upper portion 670b also opens to a recessed bottom surface 671 in the drive socket of the cap member 518.

Referring to FIGS. 36 and 37, the clip 519 includes an annular base portion 680 and two resilient prongs or stems 680a, 680b projecting upward therefrom along clip axis 683 and spaced by an axially extending gap 682 therebetween. Each stem 680a, 680b terminates at their free ends with flanges 681a and 681b including an upwardly facing cam surface 684 that can be ramped or inclined relative to the clip axis 683, or have a curvature thereto. The cam surfaces 684 aid in insertion of the clip 519 through the openings 670 and 672, and a corresponding lower stop surface 688 is provided at the prong flanged ends 681a and 681b extending normal to clip axis 683 that substantially prevents unintentional removal of the clip 519 back through the openings 670, 672.

The central opening 672 of the saddle 520 also includes an upper portion 672a and a lower portion 672b. The lower portion 672b opens to a concave bottom 700 of the saddle 520 and has a larger diameter than the upper portion 672a so that there is an annular shoulder surface 672c extending therebetween. The enlarged lower portion 672b is sized such that the base portion 680 of the clip 519 is fit and held therein in interference with the surface 672c. Preferably, the diameter of the opening lower portion 672b is kept to a minimum to increase the surface contact area of the saddle surface 700 on the rod 16. The opening upper portion 672a can be sized to have a similar diameter as that of the smaller lower portion 670a of the cap opening 670.

To assemble the cap member 518 and saddle member 520 together, initially the spring clip member 519 is axially inserted in saddle opening 672 with prong free ends 681a and 681b first inserted in enlarged lower opening 672b. With continued axial insertion, the cam surfaces 684 engage and cam against shoulder surface 672c resiliently forcing the spring prongs 680a and 680b toward each other to take up the gap 682

5 therebetween. With the prongs 680a and 680b pushed together, the lateral outer edges 684a of the cam surfaces 684 are spaced by a distance slightly less than the diameter of the opening portions 670a and 672a. This allows the clip member 519 to continue to be inserted through the opening 672 including the smaller diameter opening upper portion 672a. Depending on the distance across the undeformed prong upper edges 684a relative to the diameter of opening lower portion 672b, there may also be camming against the saddle surface 700 with some attendant prong deformation to enable the clip prongs 680a and 680b to fit into opening lower portion 672b. Once the prong ends 681a and 681b and specifically the prong surfaces 688 thereat clear the opening upper portion 672a, the clip prongs 680a and 680b return to their original undeformed state with surfaces 688 in confronting relation with upper surface 702 of the saddle 520 so that absent exerting a force to bring the prongs 680a and 680b together, the clip member 519 and saddle member 520 stay assembled together.

10 To complete the assembly process, the prong ends 681a and 681b are next axially inserted in the cap opening 670, and specifically smaller lower portion 670a thereof. Accordingly, the cam surfaces 684 cam against a lower surface 687 of the cap 518 about the central opening 670 therein which forces the resilient stems 680a, 680b together taking up the gap 682 therebetween to allow the clip prongs 680a and 680b to be inserted through the opening portion 670a. Once the clip cam surfaces 684 pass through the lower portion 670a of the cap opening 670, the stems 680a, 680b resiliently return back toward their non-flexed position. After the prong ends 681a and 681b exit the opening 670, the prongs 680a and 680b will return to their undeformed state, and the stop surfaces 688 will be facing the cap surface 671 and spaced therefrom so that there is play between the connected components, i.e. the cap 518, saddle 520, and clip 519, as shown in FIG. 42. Upon turning the cap 518 toward its locked position, the prong ends 681a and 681b re-enter the opening upper portion 670b as the saddle member 520 is driven toward the rod 16 shifting the spring clip member 519 axially therewith due to engagement of the surface 672c on the clip base 680 with the stop surfaces 688 brought into abutting engagement

with the seating surface 674 to substantially prevent the clip 519 from being unintentionally pulled back through the openings 670, 672 during cap turning to its locked position.

5 The stems 680a, 680b of the clip 519 further include an intermediate cam portion including a central, double-ramped cam surface 800. When initially prepared for implantation, the clip 519 holds the cap 518 and saddle 520 in a compact, assembled arrangement with the clip base 680 drawn into abutting engagement with the saddle opening shoulder surface 672c so that the saddle 520 is against or closely adjacent to the cap 518, as shown in FIGS. 41 and 42. In the compact arrangement, the double-ramped surface 800 is located within the cap opening 670 to hold cap 518 against the saddle 520. 10 The stop surfaces 688 at the terminal ends 681a, 681b of the stems 680a, 680b allow the cap 518 to remain in assembly with the saddle 520 in the event the cap 518 and saddle 520 are removed from the yoke 512, such as when a surgeon removes the fixation system 500 from a patient's spine.

15 More particularly, the ramp cam surfaces 800 include a lower cam surface portion 802 and an upper cam surface portion 804 that meet at a laterally common outer edge 806. Referring to FIG. 37, it can be seen that the intermediate outer cam surface edge 806 is sized approximately the same as the distance across the distal upper prong edge at 684a. As shown, the cam surface 802 is inclined away from axis 683 as it extends 20 upwardly to edge 806 while the cam surface 804 is inclined toward the axis 683 as it extends upwardly from the edge 806. Thus, during assembly, the upper cam surface 804 can assist in shifting of the prongs 680a and 680b toward each other so they can fit through cap and saddle openings 670 and 672. Similarly, when turning of the cap 518 to loosen the saddle 520 on the rod 16, the upper cam surface 804 allows the saddle 520 25 along with the clip member 519 to be drawn back axially upward.

With the cap 518 and saddle 520 assembled as shown in FIG. 42, the edges 806 will be disposed in saddle opening upper portion 670b so that the lower ramp surface 802 frictionally bears on the surfaces about the opening lower portion 670a to hold the saddle

5 upper surface 702 up against or closely adjacent the cap bottom surface 704. In addition, the ramped or inclined orientation of the cam surface 802 allows the saddle 520 to be driven downwardly or away from the axially stationary turning cap member 518. Turning of the cap member 518 toward its locked position causes the cam surfaces 802 to cammingly bear against the surfaces about opening portion 670a urging the resilient prongs 680a and 680b toward each other to allow the prongs including the edges 806 thereof to fit through the opening portion 670a. However, the axial distance between the cam surface edges 806 and the stop surfaces 688 is larger than the axial extent of the lower opening portion 670a of the saddle so that once the edges 806 clear the bottom of the opening portion 670a, the prongs 680a and 680b will be able to resiliently return toward their undeformed configuration so that the stop surfaces 688 are in interference with the seating surface 674 in the opening 670. In addition, with the saddle member 520 shifted axially downward, the cam surface edges 806 will be exposed out from the openings 670 and 672, as shown in FIG. 44.

10 15 As can be seen in FIGS. 38-40, the saddle 520 has grooves 701 along its sides 710. As mentioned above, when the saddle 520 is inserted into the yoke 512, as seen in FIG. 29, the grooves 701 receive the nub guides or detents 643 of the yoke 512, which direct the proper positioning and insertion of the saddle 520 within the yoke 512 with the yoke sides 710 guided along the interior of the yoke sidewall portions 604 and 606. The saddle 520 further has tapered ends 703, as can be seen in FIG. 38, which assists in moving the saddle 520 into or out of the yoke 512.

20 25 In addition, the bottom surface 700 of the saddle 520 is concave to engage the rod 16 in a complementary fashion. The saddle 520 also includes a distinctly profiled upper or top surface 702 designed to cooperate with a distinctly profiled bottom surface 704 of the cap 518 to cammingly shift the bottom surface 700 of the saddle 520 into locking engagement with the rod 16. More specifically, the top surface 702 of the saddle 520 has a generally horizontal and substantially flat portion 706 extending lengthwise toward each yoke sidewall portion 604 and 606 in a direction generally orthogonal to the

direction of the axis 524 of the rod 16. In this regard, the saddle 520 presents an elongate cam surface 702 that is oriented ninety degrees from the elongate cam surface presented by the surface of the rod such as in the previously described system 10.

When the saddle 520 is deployed in the locked position with the cap 518, as seen in FIG. 44, force between the cap and saddle 520 is generally transmitted through the bottom cam surface portions 820 generally positioned at lateral positions 709 of the saddle top surface 702. The positioning of the saddle 520 transversely to a rod received in the bottom surface 700 thereof allows the saddle 520 to distribute locally the forces resolved through its lateral portions to a surface contact area in a local region of the rod 16. In contrast, were the saddle 520 oriented along the longitudinal axis 16a of the rod 16, or ninety degrees shifted from that depicted, the saddle 520 providing force through its lateral ends 709 would transmit the forces through a pair of local regions disposed along the top of the surface of the rod 16 mating therewith. Such arrangement may cause fretting, or damage and wear, to the rod 16 which may lead to failure of the rod or shearing of rod and saddle fragments. Furthermore, such an arrangement may impart a stiffness to a length of the rod 16 that is undesirable for the performance of the system when the patient is permitted to move, which places stress on the system.

The top surface 702 also includes two substantially flat side cam surfaces 708 flanking and meeting the flat portion 706. Each of the cam surfaces 708 is inclined from the flat portion 706 down to lower sides 710 of the saddle 520. The edge 712 between the cam surfaces 708 to the lower sides 710 is slightly rounded to allow the cap 518 to cam easily against the edge 712. Accordingly, the faceted cam surface 702 extends about an axis that is generally normal to the rod axis 16a.

Although the top surface 702 could, alternatively, be arcuately sloped upward for receiving the bottom cam surface 704 of the cap 518, the flat portions 706 provide a preferable distribution of stress during camming action. More specifically, a round or arcuate cam surface requires a significant amount of work to be done by the camming engagement in the initial portion of the arcuate cam surface, and then that amount of

work decreases as the cam engagement travels up to the top of the arcuate cam surface. In contrast, generally flat surfaces, such as flat portions 706, provide that the work is more evenly distributed along the flat portion 706 as the mating cam surface 704 of the cap 518 is directed over the flat portions 706.

5        Upon rotation of the cap 518 relative to the saddle 520, the bottom surface 704 of the cap 518 cams against the top surface 702 of the saddle 520 so that the bottom surface 704 of the cap 518 engages the top surface 702 of the saddle 520, which shifts the saddle 520 axially away from the cap 518 and into a tight engagement with the spinal rod 16. In this regard, the cap 518 itself does not shift vertically along and within the yoke 512, instead only rotating around its central vertical axis, as the cap 518 is turned for locking of the spinal rod 16. As previously discussed, the length 690 of the clip 519 between the base portion 680 and the stop surfaces 688 are designed specifically to allow this shifting operation between the cap 518 and the saddle 520.

5        As depicted in FIG. 34, the bottom surface 704 of the cap 518 is a programmed cam surface in the same manner as the cam lock member 18 discussed above and depicted in FIGS. 8 and 10, albeit shifted ninety degrees therefrom on the cap 518 so that in the unlocked position of the cap 518, as shown in FIG. 34, the cap cam surface 704 generally extends about an axis normal to the rod axis 16a. This is because the cam surface 702 of the saddle 520 is rotated ninety degrees from that of the rod surface as previously mentioned so that the corresponding cam surface portions of the cap cam surface 704 are also shifted ninety degrees from their location on the previously described cam lock member 18, as can be seen best in FIG. 34. This also allows the cam surfaces 702 and 704 to seat in close fitting relation prior to turning of the cap 518 toward its locked position so that the cap 518 and saddle 520 have a low profile in the yoke 512 with side portions of the cap 518 extending down about the saddle 520, as can be seen in FIG. 20. Accordingly, turning the cap member 518 toward its locked position will generate a camming action on the faceted cam surface 702 of the saddle 520 in much the same manner as the cam member 18 does on the rod 16 as discussed earlier. In addition,

the bottom surface 704 includes additional cut-away recesses 720, depicted in FIG. 41. The recesses 720 are located on an interior portion of ramp surfaces 108, 110 and serve to reduce wear and deformation of the ramp surfaces 108, 110 when rotated along the saddle cam surface 702. In contrast to the cam lock member 18 discussed above, the cap cam surface 704 includes a flat central portion 704a against which the top surface 706 rests when the saddle 520 and cap 518 are in the compact configuration of FIG. 42.

Referring now to FIG. 35, the cap 518 further includes a socket 740 for receiving a driver or a portion of a rod persuader. The cap 518 has a top surface 742, a central axis of rotation 744, and a central laterally extending axis 746. The central axis of rotation 744 and the central vertical axis 21 of the yoke 512 are generally aligned and coincident (see FIGS. 41 and 19). The lateral axis 746 is drawn along the midpoints 748 of each flange 656 intersecting the rotary axis 744 at the center of the socket 740. The socket 740 in the present form has a plurality of lobes 752 including a pair of lobes 754 which have a size larger than the other lobes 752 so that the lobes 752 are generally asymmetric about the socket 740. In addition, the larger lobes 754 are diametrically opposed and oriented along an axis 756 perpendicular to the axis of rotation 744 and angularly shifted from the central lateral axis 746, preferably by approximately 10 degrees. The geometry of the lobes 752 and 754 provides a driver or rod persuader received by the receptor 740 with only two distinct mating positions, and the offset axis 756 of the lobes 754 provides a surgeon an indication of the position of the cap 518 relative to the driver or rod persuader. It should be noted that the lobes 752, 754 could be arranged and located in a plurality of orientations provided the cap 518 and instrument have, preferably, only one relative orientation therebetween for mating. Although the preferred embodiment includes the lobes 752 and 754, other geometry may be employed. The lobes 752 and 754, however, enable greater torque to be used between the cap 518 and driver than other known geometries.

In other forms of the systems 10 and 500 described above, the bone anchor member may be provided as a number of variations. For instance, a fixed screw may be

employed with the system, either as an integral component with the coupling member or as a component received in the coupling member, as has been described. In the same manner, a hook may be employed with the coupling members.

5 While there have been illustrated and described particular embodiments of the present invention, it will be appreciated that numerous changes and modifications will occur to those skilled in the art, and it is intended in the appended claims to cover all those changes and modifications which fall within the true spirit and scope of the present invention.